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Aggregation of Marginal Gains in Cardiac Surgery: Feasibility of a Perioperative Care Bundle for Enhanced Recovery in Cardiac Surgical Patients

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Objectives: **The aim of this pilot study was to assess the feasibility of a perioperative care bundle for enhanced recovery after cardiac surgery (ERACS).**

Design: **A prospective, observational study.**

Setting: **A major urban teaching and university hospital and tertiary referral center.**

Participants: **The study included 53 patients undergoing cardiac surgery before implementation of an ERACS protocol (pre-ERACS group) and 52 patients undergoing cardiac surgery after implementation of an ERACS protocol (ERACS group).**

Interventions: **Based on recommendations from a consensus review in colorectal surgery, the following enhanced recovery perioperative care bundle was applied: detailed preoperative information, avoidance of prolonged fasting periods preoperatively, preoperative carbohydrate beverages, optimization of analgesia with avoidance of long-acting opioids, prevention of postoperative nausea and vomiting, early enteral nutrition postoperatively, and early mobilization.**

Measurements and Main Results: **The authors hypothesized that length of hospital stay would be reduced with ERACS. Secondary outcome variables included a composite of postoperative complications and pain scores. Whereas the length of stay in the group of patients receiving the bundle of enhanced recovery interventions remained unchanged compared with the non-ERACS group, there was a statistically significant reduction in the number of patients in the ERACS group presenting with one or more postoperative complications (including hospital-acquired infections, acute kidney injury, atrial fibrillation, respiratory failure, postoperative myocardial infarction, and death). In addition, postoperative pain scores were improved significantly in the ERACS group.**

Conclusions: **This pilot study demonstrated that ERACS is feasible and has the potential for improved postoperative morbidity after cardiac surgery. A larger multicenter quality improvement study implementing perioperative care bundles would be the next step to further assess outcomes in ERACS patients.**

KEY WORDS: cardiac surgery, perioperative quality improvement bundles, enhanced recovery, postoperative morbidity

PROFOUND CHANGE HAS occurred during the last 2 decades, with enhanced recovery principles becoming embedded in the perioperative care of patients across a range of surgical specialties. These have challenged and reshaped traditional models of hospital care.[1,2] Favorable outcome data, coupled with political and economic drivers to improve efficiency in healthcare delivery, have resulted in increasingly diverse applications of such practice.[3] Recently, enhanced recovery pathways have been proposed for related "high-risk" specialties, such as thoracic surgery,[4] yet few published data relate to enhanced recovery after cardiac anesthesia and surgery. With reference to published literature on the perioperative management of patients undergoing enhanced recovery care, the authors proposed specific enhanced recovery interventions that may be suitable for cardiac surgery patients. The authors report on a prospective pilot and feasibility study and how a bundle of perioperative evidence-based enhanced recovery implementations has demonstrated the potential of improved postoperative outcomes.

The "aggregation of marginal gains" is a concept popularized by Sir David Brailsford, a British cycling coach whose teams achieved astonishing success while competing at recent Olympic Games and the Tour de France. The notion involves finding and exploiting small margins for improvement at every stage. In healthcare, innovation through the adoption of enhanced recovery pathways has resulted in performance improvement through similar means. Elimination of small, apparently insignificant imperfections in patient care provides cumulative benefit and contributes to improved overall outcome.

"Enhanced recovery after surgery" (ERAS), or "fast-track surgery," is a multimodal, evidence-based pathway devised to optimize the perioperative care of surgical patients. ERAS first became established in colorectal surgery almost 20 years ago, after pioneering work by Henrik Kehlet.[1,2] Compelling evidence has demonstrated that bundles of evidence-based best practice, delivered by a multidisciplinary team throughout the perioperative process, lead to an earlier return to preoperative physiologic functions after surgery than do traditional methods. Key outcomes include improved patient satisfaction and cost-effectiveness, with reduced morbidity and length of hospital stay. These refinements have led to ERAS becoming the standard of care in many European countries for patients undergoing colorectal surgery, with an expansion of its role to other surgical specialties, and from elective to emergency care.[5]

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Preliminary results of this study were presented at the Joint Annual Meeting of the Association for Cardiothoracic Anaesthetists (ACTA) and the Society for Cardiothoracic Surgery in Great Britain and Ireland (SCTS), in Manchester, United Kingdom, in April 2012.

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Overall, 36,100 cardiac surgical procedures were performed in the United Kingdom in 2013.[6] The predicted risk of patients undergoing such procedures has increased, yet in-hospital mortality from cardiac surgery has fallen from 3.7% to 2.7% in the last decade. Morbidity after cardiac surgery remains variable, however, with postoperative incidences of myocardial infarction of up to 22%,[7] delirium of 46%,[8] and acute kidney injury (AKI) of up to 30%.[9] Quality improvements including evidence-based perioperative enhanced recovery bundles may further reduce perioperative morbidity. Improved patient outcomes and utilization of resources with perioperative enhanced recovery bundles may yield substantial economic savings and increase institutional productivity.[10] The current literature suggests that specialties such as thoracic surgery have embraced enhanced recovery pathways, mainly through extrapolation of data obtained from patients undergoing colorectal surgery.[4] There remains, however, a comparative paucity of literature and, therefore, potentially a lack of clinical application, of enhanced recovery techniques in cardiac patients, with a resultant need to develop similar pathways tailored to these patients.

To evaluate the feasibility and outcome of enhanced recovery after cardiac surgery (ERACS), the authors' institution undertook a pilot and feasibility study, prospectively comparing a pre-ERACS group with an ERACS group. The authors hypothesized that an enhanced recovery pathway in cardiac surgery (including optimization of preoperative fasting and high-energy drinks, perioperative analgesia, and postoperative mobilization) implemented through perioperative bundles would reduce length of stay (primary objective) and improve perioperative outcome variables (secondary objectives).

METHODS

This study received institutional approval by King's College Hospital NHS Foundation Trust (audit project number AP1161-01).

Data were collected prospectively at a major urban teaching hospital and tertiary referral center for all patients undergoing cardiac surgery during October 2010 for the control group before implementation of the ERACS protocol (pre-ERACS group) and by the same team during July 2011 after implementation of the ERACS protocol (ERACS group). All adult patients scheduled for elective cardiac surgery, including coronary artery bypass graft (CABG) surgery, aortic valve replacement (AVR), and mitral valve and aortic root surgery—and different combinations of these cardiac surgical procedures—as well as redo cardiac surgeries, were included in the study. Patients undergoing emergency surgery or thoracic procedures were excluded. Data collection took place during patient interviews postoperatively and from review of patient notes and electronic drug charts.

The following departmental methods were part of the induction and maintenance of general anesthesia. On arrival to the operating room, all patients received intravenous midazolam (0.02-0.05 mg/kg) before induction of general anesthesia, and an arterial cannulae was inserted. Induction of anesthesia included analgesia with fentanyl (3-5 μg/kg), hypnosis with propofol, 1 to 2 mg/kg, and muscle relaxation with atracurium, 0.5 to 0.7 mg/kg. Thereafter, the trachea was intubated and mechanical ventilation started. A central catheter was placed in the right internal jugular vein, and a transesophageal echocardiography (TEE) probe was placed in the esophagus of most patients. Anesthesia was maintained with a 1-to-1.25 minimal anesthetic concentration (about 1.15-1.5 vol% of end-tidal isoflurane) that continued during bypass, or with a propofol infusion during bypass. Analgesia was maintained with fentanyl or morphine boluses and/or remifentanil infusions. Monitoring included continuous arterial blood pressure, central venous pressure, leads I and V_5 of the electrocardiogram, and nasopharyngeal temperature. TEE monitoring included assessments of left/right ventricular filling and myocardial contractility. Volume and inotropes were given to optimize preload, afterload, and myocardial contractility. Cardioprotection during cardiopulmonary bypass was provided by mild hypothermia (32°C in the majority of cases) and by intermittent cold blood St Thomas' cardioplegia, which was administered anterogradely, after cross-clamping of the aorta, via the aortic root into the coronary arteries. After cardiopulmonary bypass was discontinued, protamine was administered to reverse the heparin.

Based on recommendations from a consensus review in colorectal surgery,[11] the authors identified the following enhanced recovery interventions that could be applied to all cardiac surgical patients: detailed preoperative information for patients (including anesthesia and perioperative fluid intake), avoidance of prolonged fasting periods preoperatively, preoperative carbohydrate beverages,[12,13] optimization of analgesia,[14] avoidance of long-acting opioids, prevention and treatment of postoperative nausea and vomiting, early enteral nutrition postoperatively, and early mobilization. ERAS has its greatest evidence base in colorectal surgery; nevertheless, most of these interventions are general in nature and therefore applicable not only in colorectal surgery but also in other surgical specialties.

The detailed protocol for ERACS with preoperative and postoperative bundles is shown in Table 1. Over a period of 4 weeks, medical teams on cardiac wards received weekly teaching by dedicated cardiac practice development nurses about the preoperative bundle. The postoperative bundle of interventions was taught on the postoperative cardiac recovery unit and on cardiac high-dependency units.

The length of hospital stay was recorded, and during daily postoperative follow-up visits, a composite of postoperative complications occurring within the first postoperative week also were recorded. These included new-onset atrial fibrillation requiring medical treatment; AKI (with a raised creatinine level of more than 30% from the preoperative level); respiratory failure (new postoperative requirements of oxygen via face mask or of noninvasive or invasive respiratory support); myocardial infarction (new pathologic Q-waves or new left bundle-branch block on the electrocardiogram, angiographically documented new graft or native coronary artery occlusion, or imaging evidence of new loss of viable myocardium plus biomarker values above 5 times the 99th percentile of the normal reference range); stroke (new neurologic deficit); hospital-acquired infections or sepsis (requiring prolonged postoperative antibiotics for more than the usual 3

Table 1. Detailed Protocol for Enhanced Recovery After Cardiac Surgery With Preoperative and Postoperative Bundles

Preoperative Bundle
- Preoperative assessment clinic including detailed patient information about anesthesia and perioperative fluid intake
- Evening before surgery: carbohydrate drink, 2 to 4 × 200 mL
- On the day of surgery:
  - Clear fluids and clear carbohydrate drink, 2 × 200 mL until 2 hours preoperatively[12,13]
  - Gabapentin, 600 mg PO preoperatively[14]

Postoperative Bundle
- Opioid (morphine) infusion discontinued after extubation
- Regular intravenous ondansetron for first 48 hr postoperatively
- Analgesia after extubation: regular paracetamol and codeine with additional oral solution of morphine sulfate, if needed
- Lactulose 15 mL (10 g) twice daily, until opening of bowels
- Early postoperative mobilization (eg, sitting regularly in a chair from the first postoperative morning onwards)

postoperative days, including postoperative infections such as surgical site infections or respiratory tract infections, accompanied by prolonged increased white cell count or C-reactive protein levels requiring microbiologic review); and death.

Apart from patients' demographics, perioperative variables included preoperative fasting times (solids and liquids) and perioperative anesthetic and surgical details. In addition, pain scores at rest on postoperative days 1 to 3 (0, no pain; 1, mild pain; 2, moderate pain; 3, severe pain), nausea and vomiting, time to first bowel movement, mobilization (time to first sitting in chair), inotropes, and postoperative drugs (prescriptions, actually given) were collected from individual case report forms.

Statistical Analysis

Continuous variables were summarized as mean with standard deviation (SD) or median with interquartile range (IQR), when appropriate, and categorical data were summarized as count (percentage). Student t-test and Wilcoxon signed-rank test were used to test differences in continuous variables, when appropriate, and the chi-square test and Fisher's exact test were used for proportions, when appropriate. Statistical analyses were performed with the statistical software SPSS (version 16).

Sample Size Calculation

The authors hypothesized that with the application of the ERACS protocol, length of hospital stay would be reduced by 2 days, assuming an average length of stay of 7 days and an SD of 4 days. [15]

Group sample sizes of 50 and 50 achieved 80% power to detect a difference of 2 between the null hypothesis that both group means of the length of hospital stay are 7 days and the alternative hypothesis that the mean length of stay of group 2 is 5 days with known group SDs of 4 and 4 and with a significance level (alpha) of 0.05 using a 1-sided 2-sample t-test.

RESULTS

Patients' Demographics and Perioperative Techniques

Overall, 105 patients were included in the assessment: 53 consecutive patients in the pre-ERACS group and 52 consecutive patients in the ERACS group after implementation of the ERACS protocol.

Both groups were very similar and matched with respect to age, sex, ethnicity, body mass index, smoking habit, and premorbid status (Tables 2 and 3). In addition, surgery type, cardiopulmonary bypass times, cross-clamp times, and anesthetic techniques were similar in both groups (Tables 4 and 5).

Perioperative Outcome Variables

Whereas length of hospital stay of 6 days remained unchanged in the ERACS group ($p = 0.31$; Table 6), the total number of patients with postoperative complications (including hospital-acquired infections, AKI, atrial fibrillation, respiratory failure, cardiac tamponade, and postoperative myocardial infarction) was significantly smaller in the ERACS group ($p < 0.01$; see Table 6). Two patients in the pre-ERACS group (1 who underwent CABG surgery and AVR and the other CABG surgery) died after developing postoperative AKI and subsequent sepsis, and multiorgan failure, respectively. One patient in the ERACS group who underwent CABG and AVR surgery died after postoperative AKI, subsequent sepsis, and multiorgan failure.

As expected, the preoperative fasting times for fluids in the ERACS group were significantly reduced by about 8 hours compared with the control group ($p < 0.001$; Table 7), and preoperative fasting for solid food was similar.

The time to resumption of solid food intake was significantly shorter in the ERACS group, with 80% of patients starting on postoperative day 1 versus only 55% in the pre-ERACS group ($p = 0.007$; Table 8). Resumption of postoperative enteral fluid intake and return of bowel function were similar in both groups (see Table 8).

Postoperative pain scores throughout postoperative days 1 to 3 were significantly lower in the ERACS group (Table 9), and postoperative morphine infusions were administered for a significantly shorter period in the ERACS group ($p < 0.01$; see Table 9).

Significantly fewer patients in the ERACS group complained of postoperative nausea on day 3 (Table 10).

Table 2. Patient Demographics

	Pre-ERACS (n = 53)	ERACS (n = 52)	p Value
Age	66.5 (11.8)	68.6 (11.1)	0.34
Sex			0.87
Male	38 (71.7%)	38 (73.1%)	
Female	15 (28.3%)	14 (26.9%)	
Ethnicity			0.68
Caucasian	45 (85%)	43 (82.7%)	
Asian	6 (11.3%)	5 (9.6%)	
African	2 (3.7%)	4 (7.7%)	
BMI (mean [kg/m^2])	26.9 (4.38)	24.3 (4.32)	0.45
Smoking	16 (30.2%)	12 (23.1%)	0.41

NOTE. Data are expressed as mean (standard deviation) or number (%).

Abbreviations: ERACS, enhanced recovery after cardiac surgery; BMI, body mass index.

Table 3. Premorbid Status

	Pre-ERACS (n = 53)	ERACS (n = 52)	p Value
NYHA class of heart failure	2.2 (0.5)	2.2 (0.5)	0.79
CCS grading of angina pectoris	2.0 (0.7)	2.2 (0.5)	0.26
EuroSCORE (mean) SD	5.5 (4.0)	5.0 (3.2)	0.46
LV function			0.82
Normal	34 (64%)	35 (67%)	
Impaired	11 (21%)	14 (27%)	
Poor	8 (15%)	3 (6%)	
Diabetes			0.55
NIDDM	6 (11%)	10 (19.2%)	
IDDM	2 (3.7%)	1 (1.9%)	
Receiving medical treatment for hypertension	36 (67.9%)	30 (57.7%)	0.27
Previous MI	19 (35.8%)	22 (42.3%)	0.5
Hypercholesterolemia	30 (56.6%)	33 (63.5%)	0.47
COPD	5 (9.4%)	6 (11.5%)	0.72
PONV	1 (1.9%)	4 (7.8%)	0.16

NOTE. Data are expressed as mean (standard deviation) or number (%).

Abbreviations: ERACS, enhanced recovery after cardiac surgery; NYHA, New York Heart Association; CCS, Canadian Cardiovascular Society; LV, left ventricular; NIDDM, noninsulin–dependent diabetes mellitus; IDDM, insulin–dependent diabetes mellitus; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease, requiring treatment; PONV, known history of postoperative nausea and vomiting.

DISCUSSION

This study suggested that an enhanced recovery protocol in patients undergoing cardiac surgery (ERACS) is feasible and potentially beneficial for patients. The perioperative quality improvement bundles in this ERACS pilot study were based on previous evidence-based enhanced recovery protocols, including avoidance of prolonged fasting periods preoperatively, preoperative carbohydrate beverages, optimization of analgesia with avoidance of long-acting opioids, prevention and treatment of postoperative nausea and vomiting, early enteral nutrition postoperatively, and early mobilization.

Table 4. Surgical Variables

	Pre-ERACS (n = 53)	ERACS (n = 52)	p Value
Surgery			0.71
CABG	31 (58.5%)	30 (57.7%)	
CABG + AVR	5 (9.4%)	3 (5.8%)	
CABG + MVR	1 (1.9%)	1 (1.9%)	
AVR	8 (15.1%)	5 (9.6%)	
MVR	3 (5.7%)	7 (13.5%)	
Other	5 (9.4%)	6 (11.5%)	
CPB (time [min])	101.6 (38.1)	89.6 (29.7)	0.11
Cross-clamp (time [min])	60.7 (31.8)	58.4 (21.6)	0.63

NOTE. Data are expressed as mean (standard deviation) or number (%).

Abbreviations: ERACS, enhanced recovery after cardiac surgery; CABG, coronary artery bypass graft; AVR, aortic valve replacement; MVR, mitral valve replacement; CPB, cardiopulmonary bypass.

Table 5. Anesthetic Variables

	Pre-ERACS (n = 53)	ERACS (n = 52)	p Value
Maintenance of anesthesia			0.76
Volatile	11 (20.7%)	18 (34.6%)	
TIVA	9 (17%)	7 (13.5%)	
TIVA + volatile	33 (62.3%)	25 (48.1%)	
Analgesia			
Fentanyl	39 (73.6%)	46 (88.5%)	0.05
Morphine	36 (67.9%)	44 (84.6%)	0.05
Remifentanil	23 (43.4%)	21 (40.4%)	0.75
Inotropes			
Norepinephrine	25 (47.2%)	25 (48.1%)	0.93
Dobutamine	1 (1.9%)	2 (3.8%)	0.55
Milrinone	2 (3.8%)	4 (7.7%)	0.39
Epinephrine	0 (0%)	3 (5.8%)	0.08
Insulin	19 (35.8%)	18 (34.6%)	0.89
Last temperature in operating room (°C)	35.5 (0.69)	35.7 (0.56)	0.15

NOTE. Data are expressed as mean (standard deviation) or number (%).

Abbreviations: ERACS, enhanced recovery after cardiac surgery; TIVA, total intravenous anesthesia

Transition from existing care to a perioperative bundle of enhanced recovery interventions is not straightforward. Success from enhanced recovery depends on delivery of all intended interventions by all members of a multidisciplinary team at all points during the pathway. This extends from initial outpatient assessments through to eventual discharge. Organization of a service to enable consistent implementation of timely, coordinated interventions requires that certain fundamentals are met, including staffing levels, training, resource allocation, and full engagement with the ethos of enhanced recovery by all stakeholders. In addition, infrastructure for this comprehensive service must include appropriate safeguards and clinical governance. This trial demonstrated the feasibility of preoperative and postoperative enhanced recovery bundles, which were introduced through educating perioperative care teams, resulting in significantly reduced preoperative fasting times for liquids, earlier intake of solid food postoperatively, and improved postoperative analgesia.

The evidence base at present does not allow for determination of the comparative importance of individual components of this protocol. Protocols are subject to local interpretation, preferences, and financial circumstances. Consequently, certain interventions may be omitted and the full benefit of enhanced recovery may not be realized.

It is known that a pathway for fast-track cardiac care reduces time to extubation and length of stay in the intensive care unit.[16] One study prospectively evaluated the economic impact of a "fast-track" strategy to cardiac surgery compared with conventional recovery.[17] The "fast-track" group (n = 84) demonstrated cost-effectiveness (mean saving per patient £371) through a reduced duration of postoperative tracheal intubation and critical care unit stays compared with the conventional recovery group (n = 52). However, total hospital length of stay and rates of complications, reintubation, and readmission were similar between the groups.

Table 6. Postoperative Complications and Length of Stay

	Pre-ERACS (n = 53)	ERACS (n = 52)	p Value
Number of patients with 1 or more postoperative complications	27 (50.9%)	10 (19.2%)	<0.01
Individual postoperative complications			
Postoperative infection*	4 (7.5%)	1 (1.9%)	0.36
AKI	6 (7.5%)	2 (3.8%)	0.27
AF	15 (28.3%)	7 (13.5%)	0.06
Respiratory failure†	5 (9.4%)	1 (1.9%)	0.10
MI‡	2 (3.8%)	0 (0%)	0.16
Stroke§	2 (3.8%)	0 (0%)	0.16
Death	2 (3.8%)	1 (1.9%)	0.57
Duration of hospital stay (days), median (IQR)	6 (5-9)	6 (4-7)	0.31

NOTE. Values expressed as mean (standard deviation), number (%), or median and interquartile range.

Abbreviations: ERACS, enhanced recovery after cardiac surgery; AKI, acute kidney injury (raised creatinine of more than 30% from preoperative level); AF, atrial fibrillation requiring medical treatment; MI, myocardial infarction.

*Postoperative infection: Hospital-acquired infection or sepsis requiring prolonged postoperative antibiotics for more than 3 postoperative days, including surgical site infections or respiratory tract infections accompanied by prolonged increased white cell count or C-reactive protein levels that require microbiologic review.

†Respiratory failure: New postoperative requirement of oxygen via face mask or of noninvasive or invasive respiratory support.

‡MI (myocardial infarction): new pathologic Q-waves or new left bundle-branch block in the electrocardiogram, or angiographically documented new graft or native coronary artery occlusion, or imaging evidence of new loss of viable myocardium plus biomarker values above 5 times the 99th percentile of the normal reference range).

§Stroke: New neurologic deficit.

Many interventions explicit in ERAS protocols are not features of fast-track cardiac care pathways and are thus inconsistently applied. If such ERAS components are bundled and made explicit through an enhanced recovery cardiac care package as in the proposed ERACS protocol presented here, this may help improve outcome.

Although application of ERAS principles to cardiac surgery is appealing, to date implementation has been limited. Clear differences exist in the patient populations and the nature of the surgery among patients undergoing gastrointestinal surgery (for which ERAS is based) and patients undergoing cardiac surgery (eg, bowel manipulation leading to postoperative ileus, presence/absence of cardiopulmonary bypass, bleeding risk). Devising a pathway for cardiac surgery requires the integration of selected, validated components of existing ERAS pathways into interventions established in cardiac patients, as in the proposed ERACS protocol presented here.

Table 7. Preoperative Fasting Times

	Pre-ERACS (n = 53)	ERACS (n = 52)	p value
Fasting			
Liquids	12.25 (7.24)	4.18 (3.47)	<0.001
Solids	14.6 (6.91)	13.35 (3.16)	0.28

NOTE. Data are expressed as mean (standard deviation).

Abbreviations: ERACS, enhanced recovery after cardiac surgery.

Table 8. Postoperative Gastrointestinal Outcome Variables

	Pre-ERACS (n = 53)	ERACS (n = 52)	p Value
First postoperative intake of enteral solids			
Day 1	29 (54.7%)	42 (80.1%)	0.007
Day 2	39 (73.5%)	47 (90.3%)	0.04
Day 3	47 (88.7%)	51 (98%)	0.13
First postoperative intake of enteral liquids			
Day 1	48 (90.5%)	50 (96%)	0.35
Day 2	50 (94.3%)	51 (98%)	0.62
Day 3	51 (96.2%)	52 (100%)	0.50
Bowel opening			
Day 1	3 (5.8%)	0 (0%)	0.15
Day 2	13 (24.5%)	12 (23%)	0.804
Day 3	30 (56.6%)	35 (67.3%)	0.415

NOTE. Data are expressed as number (%).

Abbreviation: ERACS, enhanced recovery after cardiac surgery.

Interestingly these results revealed that postoperative pain scores were significantly lower in the ERACS group despite shorter periods of postoperative morphine infusions. This may have been due to greater awareness of and importance of individual components of enhanced recovery pathways by the medical teams caring for patients and also to additional preoperative gabapentin doses or increased use of intraoperative fentanyl and morphine in the ERACS group. The incidence of postoperative chronic pain was not assessed; however, improved postoperative pain might have beneficial effects on the incidence of chronic pain.

Because the cardiac patients were quite homogenoeus and there were no statistically significant differences in the baseline characteristics between the 2 cohorts, they can be regarded as matched in this study. Thus, propensity score matching was unnecessary, and straightforward comparisons of means and proportions on postoperative variables were sufficient. Because this was the nature of the study data, the authors do not believe this to be a limitation of the study.

Table 9. Postoperative Pain Scores at Rest and Opioid Infusions

	Pre-ERACS (n = 53)	ERACS (n = 52)	p value
Pain (0-3)*			
Day 1	1.7 (0.9)	1.1 (0.9)	<0.01
Day 2	1.3 (0.8)	0.9 (0.6)	<0.05
Day 3	0.9 (0.8)	0.4 (0.7)	<0.01
Opioid infusion			
Morphine	52 (94.3%)	50 (96.2%)	0.62
Fentanyl	1 (1.9%)	2 (3.8%)	
Duration (days)	3 (2-3)	0 (0-0)	<0.01

NOTE. Data are expressed as mean (standard deviation), number (%), or median and interquartile range.

Abbreviations: ERACS, enhanced recovery after cardiac surgery; SD, standard deviation.

*0, no pain; 1, mild pain; 2, moderate pain; 3, severe pain.

Table 10. Number of Patients Complaining of Postoperative Nausea and Vomiting

	Pre-ERACS (n = 53)	ERACS (n = 52)	p value
Nausea			
Day 1	26 (49%)	22 (42.3%)	0.42
Day 2	20 (37.7%)	11 (21.1%)	0.71
Day 3	22 (41.5%)	9 (17.3%)	<0.05
Vomiting			
Day 1	14 (26.4%)	12 (23.1%)	0.62
Day 2	7 (13.2%)	4 (7.7%)	0.26
Day 3	5 (9.4%)	1 (1.9%)	0.24

NOTE. Data are expressed as number (%).
Abbreviation: ERACS, enhanced recovery after cardiac surgery.

Study Limitations

The authors have not conducted an ERACS as a proof-of-concept randomized controlled trial. Feasibility of implementation of quality improvement bundles, however, probably is greater in groups of patients grouped by perioperative teams rather than in individual patients only. Therefore, a successful implementation is more likely in a cohort over time than in individual patients. A multicenter trial design with cluster randomization would be a possible next step for a proof-of-concept trial. This would confer the advantage of larger numbers of patients and greater statistical power for assessments of clinically significant improvements of single postoperative outcome variables.

In addition, formal perioperative fluid management or goal-directed therapy (GDT) based on pulmonary artery catheter or esophageal Doppler measurements were not included in this pilot study. Nevertheless, intraoperatively, preload was optimized in both groups according to regular transesophageal echocardiographic assessments in the majority of patients, which included the left and right ventricular filling status. Recently, a meta-analysis demonstrated that GDT in cardiac surgery had the potential to reduce postoperative morbidity and length of hospital stay, but not mortality.[18] Therefore, whether outcomes might be further improved with a formal postoperative (nurse-led) GDT protocol remains open.

This study demonstrated a neutral result regarding length of hospital stay. Future trials are necessary to assess whether potentially improved postoperative morbidity with ERACS also is associated with a reduced length of stay and thus potentially improved costs.

Apart from the perioperative outcomes assessed in this pilot study, additional variables in future studies also could include patient satisfaction scores, readmission rates to the intensive care unit, quality-of-life assessments, disability-free survival,[19] and longer follow-ups.

This pilot study demonstrated feasibility and the potential for improved postoperative morbidity with the implementation of an enhanced recovery bundle of interventions in patients undergoing cardiac surgery.

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